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# Trade Liberalization and Endogenous Growth in a Small Open Economy

## A Quantitative Assessment

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Although trade liberalization has been linked econometrically and through casual empiricism to large income increases, attempts to quantify its impact in static simulation models have shown estimated gains. This paper shows that when the endogenous dynamic effects of trade liberalization are built into simulation models, the estimated gains are indeed very large. But complementary regulatory, financial market, and macroeconomic reforms are important to realize the largest gains.



## Summary findings

Rutherford and Tarr develop a numerical endogenous growth model approximating an infinite horizon, which allows them to investigate the relationship between trade liberalization and economic growth.

Economic theory generally implies that trade liberalization will improve economic growth, and the two phenomena are positively correlated in empirical tests, but the connection is not well-substantiated in numerical general equilibrium models.

In the authors' model, an intermediate input affects aggregate output through a Dixit-Stiglitz function. Additional varieties provide the engine of growth in this framework and the existence of this mechanism magnifies the welfare costs. In this model with lump sum revenue replacement, reducing a tariff from 20 percent to 10 percent produces a welfare increase (in terms of Hicksian equivalent variation over the infinite horizon) of 10.7 percent of the present value of consumption in

their central model, where the economy is assumed to be unable to borrow on international financial markets. If macroeconomic and financial reforms are in place that would allow international borrowing, however, the same tariff cut is estimated to result in a 37 percent increase in Hicksian equivalent variation. On the other hand, if inefficient replacement taxes must be used in an economy without the capacity to borrow internationally, the gains would be reduced to 4.7 percent. Larger tariff cuts — typical of those in many developing countries over the past 30 years — produce larger estimated welfare gains at least proportionate to the size of the cut.

The authors apply the model to five developing countries and estimate the impact of the tariff changes those countries plan to undertake as part of Uruguay Round commitments. Because of the dynamic effects, estimated gains are considerably larger than those found in the literature on the impact of the Uruguay Round.

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**Trade Liberalization and Endogenous Growth**  
**in a Small Open Economy: A Quantitative Assessment**

by

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## 1. Introduction

International trade economists have typically argued that an open trade regime is very important for economic development. This view has been based partly on neoclassical trade theory, which generally finds that a country improves its welfare from trade liberalization, partly on casual empirical observation that countries which remain highly protected for long periods of time appear to suffer significantly and perhaps cumulatively, and partly on systematic empirical work that also finds trade liberalization beneficial to welfare and growth (e.g., Sachs and Warner, 1995).<sup>1)</sup> What has been troubling is that the numerical modeling estimates of the impact of trade liberalization have generally found that trade liberalization increases the welfare of a country by only about one-half to one percent of GDP, gains which are very small in relation to the paradigm.<sup>2)</sup> For many years authors have claimed that the welfare gains from trade liberalization would be much larger if the dynamic impact of trade liberalization were taken into account, but heretofore no such models have been developed.<sup>3)</sup>

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<sup>1)</sup>Of course, all aspects of the paradigm that trade liberalization leads to faster growth have been subject to criticism. For example, Rodrik (1992) has developed models in which trade liberalization is immiserizing, and causality has been questioned in the Sachs and Warner results.

<sup>2)</sup>See, for example, de Melo and Tarr (1990; 1992; 1993); Harrison, Rutherford and Tarr (1993; 1997a; 1997b); Morkre and Tarr (1980; 1995); and Tarr and Morkre (1984). The consistently small estimated gains in constant returns to scale models came to be known as "the Harberger constant." While some estimates with increasing returns to scale models (such as Harris, 1984) have been larger (up to 10 percent of GDP), these estimates have been more controversial, often based on regime switching (see Harrison, Jones et al., 1993; and Harrison, Rutherford and Tarr, 1997a). In our view, the results are less than convincing for a strong version of the paradigm.

<sup>3)</sup>Moreover, we have shown, see Rutherford and Tarr (1997), that a comparative static model may be a close approximation to the annual welfare gains from trade liberalization in a dynamic model, if the dynamic model is simply Ramsey based, i.e., if there is no endogenous growth.

Some numerical general equilibrium modelers have produced comparative "steady state" estimates of the welfare gains which are two to four times the comparative static estimates of their models (e.g., Harrison, Rutherford and Tarr, 1996, 1997; Francois, McDonald and Nordstrom, 1996; and Baldwin, Francois and Portes, 1997). These are multi-sector quantifications of the Baldwin (1989) "medium term growth bonus," which hold the rental rate on capital constant and allow the capital stock to vary. Harrison, Rutherford and Tarr (1996; 1997a) and Rodrik (1997) have explained, however, that these estimates overestimate the gains from trade liberalization in a Ramsey type model because they fail to adjust for the foregone consumption cost of achieving the higher capital stock.

With the development of endogenous growth theory (for example, Romer (1990), Romer and Rivera-Batiz (1991), Grossman and Helpman (1991) and Segerstrom, Anant and Dinopoulos (1990)) a clear theoretical link has been provided from trade liberalization to economic growth. Due to the complexity of the models, however, the theoretical literature has necessarily focused on a comparison of the steady-state growth paths, and been based on rather aggregated models. Since two policies that achieve the same steady-state growth path could have very different welfare consequences, it is important to develop models that derive the dynamic adjustment path and evaluate the welfare effect.

In this paper we develop a dynamic small open economy model defined over a 54 year horizon, from 1997 to 2050 with terminal constraints which approximate an infinite horizon. There are two sectors  $X$  and  $Y$ . The  $Y$  sector produces goods for domestic and export markets under constant returns to scale (CRTS). Inputs into  $Y$  are labor and a pure intermediate good  $X$ . The good  $X$  is produced by both foreign and domestic firms under the large group monopolistic competition assumption and increasing returns to scale (IRTS).<sup>4</sup>

We employ the by now standard assumption that inputs of  $X$  affect the production of  $Y$  according to a Dixit-Stiglitz function. This means that additional varieties of  $X$  reduce the cost of producing  $Y$ . Firms in the IRTS sector must incur a once and for all fixed cost of a "blueprint" in order to introduce a new product; and firms also incur a fixed cost in any period in which they operate. Domestic firms use relatively more local inputs and relatively less imported inputs. Product development costs are lower for foreign firms under the assumption that in relation to the size of the domestic market there is an infinite stock of varieties of

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Nonetheless, the estimates for Hicksian equivalent variation remain less than five percent of GDP, except for the Baldwin, Francois and Portes paper; and Rodrik (1997) has estimated that after adjusting for the foregone consumption cost of investment, the estimated equivalent variation in the Baldwin, Francois and Porter paper would also be less than five percent.

<sup>4</sup>Our analysis can be viewed as an extension of Ethier (1982) and Markusen (1989, 1991). Markusen investigated the implications of the substantial trade in imported intermediate inputs using static and two period models. A previous model of ours, Rutherford and Tarr (1996), also employed an Ethier-Dixit-Stiglitz framework to evaluate the impact of trade liberalization. In that paper, however, the growth rate was not affected endogenously, so the additional welfare gains from the variety effect were derived from transitional dynamics.

products on international markets; thus, their development costs represent solely the cost of adapting and introducing a product from the international market to the domestic economy. All agents in the model, including firms in the IRTS sector, optimize over the infinite horizon with perfect foresight apart from unanticipated policy changes.

In our central model, the country cannot borrow on international capital markets, so that the value of imports must be covered by exports in each period of the model. We investigate the impact of allowing capital flows in the sensitivity analysis.

The only tax distortion in the economy in the benchmark data set is a twenty percent tariff on imports. We first construct a steady state growthpath with which we can compare results of counterfactual experiments. We then reduce the tariff to ten percent and compare all variables to their values in the benchmark steady-state.

We construct a series of counterfactual scenarios to determine the sensitivity of the results to tax, macro and financial policies, as well as to different tariff cuts and parameter specification. We evaluate the welfare consequences of a change in policies, i.e., we report the Hicksian equivalent variation for the infinitely-lived representative agent.

Some of our most important results are as follows: with lump sum revenue replacement, reducing a tariff from 20% to 10% produces a welfare increase (in terms of Hicksian equivalent variation over the infinite horizon) of 10.7 percent of the present value of consumption in our central model. We investigated the sensitivity of our results to all of the key parameters in the model and found that the welfare estimates for the same tariff cuts ranged up to 37 percent with capital flows, and down to 4.7 percent with inefficient replacement taxes. Doubling or quadrupling the size of the tariff cuts, which would characterized the experience of many developing countries in the past 30 years, resulted in estimates of the welfare gains that were at least twice or four times, respectively,

the size of the cut. We applied the model to five developing countries and estimated the impact of the tariff changes which they plan to undertake as part of their Uruguay Round commitments. Our estimated gains are large in relation to the literature estimates of the impact of the Uruguay Round.

Our results illustrate the crucial importance of complementary reforms to fully realize the potential gains from the trade reform. Notably, with the ability to access international capital markets, the gains are more than doubled. Moreover, use of inefficient replacement taxes will significantly reduce the gains. These combined results show that complementary macroeconomic, regulatory, and financial market reforms to allow capital flows and efficient alternate tax collection are crucial to realize the potentially large gains from trade liberalization.

Large welfare gains in the model arise because the economy benefits from increased varieties of foreign  $X$  in the short run, and increased varieties of domestic  $X$  after several years. In order to assess the importance of variety gains, we perform the tariff reform in a constant returns to scale, perfect competition Ramsey model; then additional varieties do not increase total factor productivity. In this model the Harberger constant reemerges, as welfare gains are about 0.5 percent of the present value of consumption.

We apply our model to datasets for five countries: Argentina, Brazil, Korea, Malaysia and Thailand, and assess the effects on these economies of the tariff changes they agreed as part of their Uruguay Round commitments. The relatively large welfare gains that we estimate for these five countries relative to the literature estimates of the gains from the Uruguay Round for these countries, suggest that the large welfare gains in our stylized model are not based on implausible parameter values.

Although estimates of equivalent variation have been widely seen as too small, some may question whether our estimates are too large. To put these numbers in perspective, in appendix A we have analytically derived the relationship between a permanent increase in the steady state growth rate and equivalent variation. A welfare gain of between 10 and 35 percent of consumption corresponds to a permanent increase in the growth rate of between 0.4 and 1 percent. A policy induced change in the growth

rate of this magnitude is quite plausible in the context of the actual long term per capita growth rates over the 25-30 year period beginning in 1962. The highest average long term annual growth rates are for the four "East Asian tigers," with rates over 6 percent (Korea at 6.7 percent is the highest). At the other extreme there are 17 countries, largely in Africa, with negative growth rates, three of which are less than negative 2 percent. The average per capita growth rate for developing (developed) countries as a whole is 1.6 (2.9) percent with a standard deviation of the growth rate of 2 (1).<sup>5)</sup>

Sachs and Warner (1995) maintain that this large range and standard deviation of the growth rates across developing countries is explained in large part by trade liberalization. Based on cross-country growth regressions, they estimate that open economies have grown about 2.45 percent faster than closed economies, with even greater differences for open versus closed economies among developing countries. They note that trade liberalization is often accompanied by macro stabilization and other market reforms, and their open economy variable can be picking up these other effects as well.<sup>6)</sup> But they argue that trade liberalization is the *sine qua non* of the overall reform process, because other interventions such as state subsidies often are unsustainable in an open economy. While, like Sachs and Warner, our results show that trade liberalization can have an important impact on growth, we also find that the benefits of trade liberalization can be dissipated without complementary reforms in the macroeconomic, financial and tax areas.

These econometric estimates suggest that our estimate of equivalent variation, which corresponds in our central model to a growth rate change of 0.4 percent, may still be too small. But larger tariff changes

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<sup>5)</sup>These estimates are taken from Pritchett (1997), who performed the calculations based on the Summers and Heston (1991) data.

<sup>6)</sup>Because trade policy may be endogenous, some have criticized the Sachs and Warner OLS estimates as suffering from simultaneity bias. Ann Harrison and Dani Rodrik (1997) have provided preliminary estimates, however, that show that the impact of trade liberalization on growth is even larger when the simultaneity bias is taken into account; in particular, a ten percent reduction in the tariff as we have simulated above, is estimated to increase the growth rate by considerably more than our estimate of 0.3 percent. In addition, they show that the black market premium plays an equally important role as tariff reduction. Although Sachs and Warner take the black market premium as part of their openness measure, Harrison and Rodrik separate it and prefer to think of it as a proxy for macro stabilization.



than our ten percent cut produce larger welfare gains and correspond to higher changes in the growth rates.

On the other hand, Young (1995) has estimated that the majority of the growth among the four East Asian tigers is explained by factor accumulation, not increases in total factor productivity. But even Young has found that average annual total factor productivity growth was equal to 1.7 percent in South Korea, 2.1 percent for Taiwan and 2.3 percent for Hong Kong. Only Singapore had virtually zero growth in total factor productivity according to Young's estimates. Using Young's data,<sup>7</sup> however, but correcting for a bias in the estimation procedure, Rodriguez-Clare (1997) estimates that a much larger share (almost 60 percent ) of the growth among these four countries is due to an increase in TFP. We conclude that a detailed examination of the East Asian tigers leaves a sufficient role for policy in explaining growth that our equivalent variation estimates are not excessive.

Since our model employs the Chamberlinian large group assumption, the markup over fixed costs remains unchanged, so there are no rationalization gains. Thus, these calculations show that the Ethier-Dixit Stiglitz characterization of production, where additional varieties lowers costs, is sufficient to generate the large welfare gains and increase in per-capita income. We have also developed a model in which there are positive spillovers from additional foreign varieties on the costs of introducing new domestic varieties. Although the domestic industry recovers more rapidly, the welfare gains are not significantly affected, since additional domestic varieties come largely at the expense of foreign varieties. Since the existence of spillovers is somewhat controversial, the robustness of our results with respect to spillovers provides support for the variety-trade liberalization paradigm.

The remainder of this paper is organized as follows. Section 2 outlines essential features of our model. Section 3 presents results and sensitivity analysis with respect to model structure. The application

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<sup>7</sup>For Singapore, Rodriguez-Clare corrected for inconsistencies in the data.

of the model to the Uruguay Round commitments of five developing countries is presented in Section 5. Section 6 concludes. Appendix A provides further details on welfare calculations over an infinite horizon, relating changes in the economic growth rate to infinite-horizon welfare and then show how we apply these results to approximate infinite horizon welfare. Appendix B describes the stylized benchmark data set and model calibration.

## 2. Model Formulation

We consider a two sector economy. The  $Y$  sector produces exports and final goods for the domestic market under constant returns to scale (CRTS) and perfect competition. The  $X$  sector which is composed of both domestic and foreign firms produces intermediate goods under increasing returns to scale (IRTS) and imperfect competition with a Dixit-Stiglitz representation of the impact of increases in the number of products on total factor productivity. Markups on goods in the IRTS sector are based on the Chamberlinian large group assumption--that is, the elasticity of demand facing the representative firm is equal to the compensated elasticity of substitution between varieties. Final demand arises from an infinitely-lived representative agent who is at the margin indifferent between an additional unit of consumption and an additional unit of investment. In this section we outline the key features of the model in terms of the objectives and constraints facing various agents.

### 2.1 Consumer Behavior

The intertemporal utility function of the infinitely lived representative consumer is the discounted sum of the utility of consumption over the horizon:

$$U = \left( \sum_t \Delta^t C_t^p \right)^{\frac{1}{p}}$$

In this equation the parameter  $\rho$  controls the intertemporal elasticity of substitution<sup>9)</sup> and  $\Delta$  is the single period discount factor. Aggregate consumption in a given period ( $C_t$ ) is a Cobb-Douglas aggregate of consumption of domestic and imported final goods:

$$C_t = CD_t^{\alpha_D} CM_t^{1-\alpha_D}$$

We assume that imported final goods cannot be produced in the home market, due to technical limitations of the domestic final goods sector. The agent's intertemporal and within-period consumption decisions are weakly separable. Thus, the typical static first order condition applies on consumption decisions within a time period, given a decision on how much to spend on consumption in any period. In the standard manner, the intertemporal decision is based on the maximization of the utility function subject to the constraint that the present value of consumption equals the present value of income:

$$\begin{aligned} \max U &= \left( \sum_t \Delta^t CD_t^{\alpha_D \rho} CM_t^{(1-\alpha_D) \rho} \right)^{\frac{1}{\rho}} \\ \text{s.t.} \quad (1 + \tau_c) &\left( \sum_t p_t^D CD_t + \sum_t p_t^M CM_t \right) = \sum_t w_t \bar{L} + \Pi_0 \end{aligned}$$

In this expression, all prices are defined in present value terms, discounted to period 0 (=1997). The right side of the constraint, which is the present value of income, includes the present value of wage income<sup>9)</sup> together with profits from existing capital stocks and patents.  $\tau_c$  is the consumption tax, discussed below. In a steady-state equilibrium, there are no pure profits, but along an adjustment path moving to a new steady state there may be returns associated with existing capital and markups over marginal cost. In other words,

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<sup>9)</sup> The intertemporal elasticity of substitution  $\sigma_T = 1/1-\rho$ . See table 1 for the assumed values of elasticities in different sectors.

<sup>9)</sup> Note that population is fixed over the time horizon. Economic growth results solely from productivity improvements due to the accumulation of varieties, and the real wage increases over time relative to the prices of domestic output and imports.

pure profits and losses are only associated with current (extant) firms. All firms formed during the model horizon earn zero economic profit.

## 2.2 Government Revenue and Expenditure

The government provides public goods and services at an exogenous level through the infinite horizon. While we presume that these goods are provided because they generate net benefits for the representative consumer, we do not formally model the impact of public provision on consumer well-being. Instead, we account for the cost of providing public sector services through the imposition of an equal-yield constraint asserting that any change in tariff rates must be compensated by a permanent change in one of three alternative domestic tax instruments. The government purchases domestic final output (GD) and imported final output (GM) to assure that a given level of public provision is maintained, i.e.

$$GD_t^{\alpha_D} GM_t^{1-\alpha_D} = \bar{G}_t$$

The public sector budget constraint (which determines the replacement tax rate) is then written in present value terms as:

$$\sum_t \left( p_t^D GD_t + p_t^M GM_t \right) = \sum_t \left( T_t^M(t_t^M) + T_t^C(\tau_C) + T_t^K(\tau_K) + T_t^Y(\tau_Y) \right)$$

In this equation the sum on the left represents the cost of public expenditures, and the sum on the right represents tax revenue from tariffs, consumption taxes, capital income taxes and final output taxes, respectively. The tariff rates ( $t_t^M$ ) are exogenously specified policy variables, whereas the tax rates on consumption, capital income and output are determined endogenously to assure that the government budget constraint is satisfied.<sup>10)</sup>

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<sup>10)</sup> In any equilibrium only one of the replacement tax instruments is non-zero, depending on the scenario-specific replacement tax option.

### 2.3 Sales and Production of the Final Good

Good  $Y$  is produced as differentiated products for sale in the domestic and international markets. The shares of sales at home and abroad are determined by relative prices. This is effectively an Armington-style differentiation of products in the export market. A constant elasticity of transformation (CET) function relates the composite output level in a given period to domestic and export sales. Firms producing the final good maximize profit subject to the constraint:

$$Y = \left[ \eta_D \left( \frac{D}{\bar{D}} \right)^{1+\eta} + (1-\eta_D) \left( \frac{E}{\bar{E}} \right)^{1+\eta} \right]^{\frac{1}{1+\eta}}$$

In this equation parameters  $\bar{D}$  and  $\bar{E}$  are the base year (1997) levels of output to the domestic and export markets, and  $\eta_D$  is the baseline value share of domestic sales in total sales (the base year production level is scaled to unity).

Production of the  $Y$  composite is associated with a nested production function based on inputs of labor ( $L$ ) and differentiated intermediate inputs ( $x_i$ ). Given prices of intermediate goods and labor, the aggregate production sector operates so to minimize the costs of producing a given output subject to the constraint:

$$Y = \bar{L}^{1-\alpha} \left[ \sum_{i=1}^N x_i^\rho \right]^{\alpha/\rho} = \bar{L}^{1-\alpha} \left[ \sum_{i=1}^{N_D} x_{iD}^\rho + \sum_{i=1}^{N_F} x_{iF}^\rho \right]^{\alpha/\rho}$$

In this function, the intermediate inputs and labor enter in a Cobb-Douglas aggregate with value shares determined by base year demands. It is evident from the production function that we have firm level rather than national product differentiation. Since costs of varieties can differ by foreign or domestic origin, at the second level, within the intermediate input ( $X$ ) nest, we account for substitution between domestic and foreign varieties according to a constant-elasticity-of-substitution aggregation. The inputs of intermediates

from domestic and foreign firms represent the *effective supply* of  $X$  from these firm types. The effective supply of all type  $f$  firms is described by:

$$X_f \equiv \left( \sum_{i=1}^{n_f} x_{if}^\rho \right)^{1/\rho} = \left( n_f x_f^\rho \right)^{1/\rho} = n_f^{\frac{1-\rho}{\rho}} \tilde{X}_f \quad f \in \{D, F\}$$

in which  $x_{if} = x_f$  (by symmetry) is output of a representative type  $f$  firm,  $\tilde{X}_f = n_f x_f$  is the total output from type  $f$  firms. Holding total output from type  $f$  firms constant, effective supply from type  $f$  firms increases with  $n_f^{\frac{1-\rho}{\rho}} = n_f^{\frac{1}{\sigma-1}}$ , which is the "variety effect multiplier." The multiplier increases with  $n_f$  and increases as  $\sigma$

decreases toward 1 ( $\sigma > 1$ ). (The second equation in this expression reflects our assumption of symmetric firm structure.) We then may express the aggregate production function as:

$$Y = \bar{L}^{1-\alpha} \left[ n_D^{1-\rho} \tilde{X}_D^\rho + n_F^{1-\rho} \tilde{X}_F^\rho \right]^{\alpha/\rho}$$

Following Romer and others, we assume that the value share of  $X$  in aggregate production is related to the elasticity of substitution between varieties so that  $\alpha = \rho$ , which implies that the elasticity itself is defined by the value share as  $\sigma = 1/(1 - \alpha)$ . Making this substitution, we have the following expression for aggregate output:

$$Y = \left( n_D \bar{L} \right)^{1-\alpha} \tilde{X}_D^\alpha + \left( n_F \bar{L} \right)^{1-\alpha} \tilde{X}_F^\alpha$$

## 2.4 Market Clearance Conditions

Output of the good  $Y$  supplied to the domestic market can be consumed or invested. Investment in  $X_D$  and  $X_F$  sectors involve forgone consumption of domestic output. The market clearance for macro output sold in the domestic market is given by:

$$D_t = CD_t + GD_t + \sum_{f \in \{D,F\}} \left[ \beta_f^D B_{ft} + I_{ft} + n_{ft} \left( \alpha_f + a_{ft}^D x_{ft} \right) \right]$$

This equation states that domestic output is purchased by households ( $CD_t$ ), government ( $GD_t$ ) and firms.

In turn, each firm type has four sources of demand for domestic output: (i) inputs to blue-print design ( $\beta_f^D B_{ft}$ ), (ii) inputs to physical capital formation ( $I_{ft}$ ), (iii) recurring fixed costs ( $n_{ft} \alpha_f^D$ ) and (iv) variable costs of production ( $n_{ft} a_{ft}^D x_{ft}$ ). Both firm types (domestic and foreign) are treated symmetrically, although we adopt parameters reflecting a relatively larger share of domestic inputs for the domestic firm. Domestic firms are assumed to make investments in plant and equipment, whereas foreign firms who generally import all the key components invest solely in distribution facilities such as warehouses and transportation equipment.

The corresponding supply-demand balance for imported goods is as follows:

$$M_t = CM_t + GM_t + \sum_{f \in \{D,F\}} \left( \beta_f^M B_{ft} + n_{ft} a_{ft}^M x_{ft} \right)$$

Thus, imports enter into final demand by consumers and government and intermediate demand by firms. Imported inputs ( $\beta_f^M B_{ft}$ ) are required to establish either a domestic or foreign firm and are also required for the fixed costs of operation ( $n_{ft} a_{ft}^M x_{ft}$ ).

## 2.5 Capital Stock Evolution

In our model, capital is firm-specific following installation, and investment rates may fall to zero as a consequence of unanticipated changes in policy parameters. Following a standard Solow growth model, investment in period  $t$  produces a unit of additional capital in the following year which may be used for production in the future. Physical capital stock depreciates at a constant geometric rate:

$$K_{ft+1} = \lambda K_{ft} + I_{ft} \quad f \in \{D, F\}$$

whereas the number of blueprints (=number of firms) of each type are permanently in the market after they are produced:

$$n_{ft+1} = n_{ft} + B_{ft} \quad f \in \{D, F\}$$

## 2.6 Firms and Production Varieties

In sector  $X$  there is a one to one correspondence between firms and product varieties. The production of good  $X$  involves both fixed and variable costs. Variable costs include inputs of aggregate output (domestic and imported) and capital. Fixed costs can have two components: (i) "overhead", a recurring fixed capital cost which is incurred in every period that the firm operates, and (ii) "setup costs", a one time research and development (or blueprint) cost that must be incurred in order to design and market a new product. The relative importance of blueprint and overhead costs are different for domestic and foreign firms. We assume that foreign firms sell products which have been designed abroad, so their setup costs represent only the cost of adapting an existing design to the domestic market. We model the production of blueprints by both types of firm through the input of domestic and imported aggregates in fixed proportion. We assume in the present model that there is no international trade in blueprints. Hence domestic firms may not license designs but must purchase resources to develop new products from scratch.

We assume that most of the costs for foreign firms selling in the domestic market are associated with capital services and imported goods. In this setting the foreign firm's fixed costs of production may be interpreted as the cost of maintaining a distribution system within the country.

The model is deterministic and firms have perfect (point) expectations of future prices. Hence, a new firm will enter at time  $t$  if and only if there are positive net quasi-rents. This happens when the present value



of markup revenue<sup>11)</sup> over marginal costs into the future is equal to or greater than the present value of the fixed costs of operation, including fixed operating costs (for foreign and domestic firms) and the fixed costs of product development (for domestic firms). It is possible to interpret this decision using Tobin's  $q$  theory (see Baldwin and Forslid, 1996). The rate of investment in blueprints occurs to the point that the stock market value of the net income (i.e., the present value of net surplus) equals the replacement costs, namely the marginal cost of a blueprint, since R&D is perfectly competitive.

The Dixit-Stiglitz production function for good  $X$  is perfectly symmetric with respect to domestic and foreign firms, i.e, we have firm level product differentiation, with no brand ornational preferences. Varieties of different vintages are equally preferred but differentiated. In this framework, all domestic firms that operate sell the same quantity of output and their varieties sell for the same markup-inclusive price. Likewise all foreign firms which operate sell the same quantity at the same price. Domestic and foreign firms enter symmetrically in the final goods production function so the derived demand for domestic and foreign intermediates is symmetric; but they remain differentiated and their prices may therefore differ. Since foreign and domestic firms are treated differently regarding their cost structures, their prices usually differ.

Furthermore, we assume that any firm producing at time  $t$  produces the same quantity as all other firms irrespective of vintage, but differing according to whether it is foreign or domestic. This implies that the share of total output produced by firms of vintage  $v$  is equal to the share of vintage  $v$  firms in the total number of firms. These life cycle assumptions impose a symmetric structure on the equilibrium which makes it possible to account for the share of markup revenue available in any period received by firms of vintage  $v$ .

Unlike our previous model in which we tracked the level of investment for all vintages through the model horizon, in the present model we achieve a considerable simplification by introducing a state variable

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<sup>11)</sup> This may be called "operating surplus", "operating profit" or "Ricardian surplus" by different authors.

for each firm type which tracks the present value of future markup earnings. This effectively treats the human capital embodied in blueprint designs in the same analytic framework as is conventionally applied to physical capital formation. The underlying logic is unchanged from the previous model – the free-entry assumption assures zero profit over the infinite horizon, and the time path of future prices affect not only investment activity but the decisions by firms to enter markets and undertake product development. Optimization over the infinite horizon applies not only to consumers and competitive firms, but also to the managers of monopolistically competitive firms.

Our model is one of a small open economy. In particular, we assume that the small open economy has only a negligible impact on the number of varieties available on world markets, and the cost of blueprints for foreign firms. In general, we observe that there are many more varieties of products available on world markets than are available in the small open economies. Accordingly, we assume that the decision facing foreign firms is how many of the products for which blueprints already exist can be profitably introduced in the local economy. The cost of the blueprint is a much smaller component of the cost of production for foreign firms than for domestic firms -- and a larger fraction of the fixed costs of operation are associated with recurring fixed costs of selling in the domestic market.

In the next section we investigate the properties of our model using numerical methods in which we calibrate coefficients of utility and production functions to a reference growth path. In the results that follow, we have assumed baseline data corresponding to table 1. These input parameters are reconciled to produce the benchmark social accounts shown in table 2. For details on the translation of input data to model parameters, see Appendix B.

### 3. Model Results

We consider a 54 year model horizon, defined over the years 1997-2050. Initially there is only one distortion in the economy: a twenty percent tariff on imports of both good  $X$ , the pure intermediate good produced under IRTS and monopolistic competition, as well as the final good, produced under CRTS. In order to establish a point of reference we calibrate a model to a "benchmark" steady-state equilibrium. In our central counterfactual scenarios, we reduce the tariff from 20% to 10% on an ad valorem (net) basis and compare the results in all scenarios to the benchmark steady-state equilibrium with the initial tariff in place. Unless otherwise indicated, all key variables are reported as a percentage of their values in the benchmark steady-state equilibrium.

In table 3 we present six model variants or scenarios. In our central model, we assume there are no spillovers from the entry of foreign firms and that the lost tariff revenue is replaced by a lump sum tax on consumption. In our second model, we allow for spillover effects of the entry of foreign firms which reduce the costs of developing blueprints by domestic firms. In the third model, we assume all sectors operate under constant returns to scale and perfect competition; then there is no productivity boost in the  $Y$  sector as a result of additional varieties of the  $X$  good.

In all of our models we impose an "equal yield constraint" regarding government revenue. Unless otherwise stated, the reduction in tariff revenue is offset by a consumption tax. Given the absence of a labor-leisure choice, this is equivalent to a lump sum tax. We examine the impact of employing a final output tax or a tax on capital as the replacement tax in the fourth and fifth models presented in table 3.

In our central model and unless otherwise stated, we assume that the country has difficulty accessing international capital markets. This may be because it has imposed restrictions on financial flows, or because macroeconomic conditions in the country are such that it can not attract international investors. We take a polar version of this assumption and assume that the country faces a balance of trade constraint in each

period, i.e., the value of its exports must equal the value of its imports (both at world prices) in each period. We relax this constraint in the sixth model, where we allow the home country to borrow on international capital markets provided any borrowing is repaid within the model horizon. Then, the present value of exports must equal the present value of imports over the model horizon.

In all scenarios we present the Hicksian equivalent variation (EV). The EV is based on the intertemporal utility function optimized over the 54 year model horizon, with an approximation for the infinite horizon. We present EV in percentage terms, where the denominator is the present value of benchmark consumption over the infinite horizon. In the figures, we present the 54 year time path for key variables in percentage change relative to the steady-state. The variables we report are as follows: Figure 1: Final Consumption, composite of domestic and imported final goods; Figure 2: Real Exchange Rate; Figure 3: Rental Rate on Capital; Figure 4 and 5: Number of Domestic and Foreign Firms, respectively; Figure 6: Consumption Paths for Alternate Replacement Taxes.

### **3.1 Tariff Reduction with Central Assumptions**

We first consider the scenario in which we cut all tariffs from 20% to 10%. In this scenario, Hicksian equivalent variation (EV) increases by 10.7 percent of the present value of consumption over the infinite horizon.

What is driving these results is the following. The removal of the tariff on imported intermediates results in an increase in the tariff ridden demand curve for imports and an increase in the price foreign firms receive for their products. This increases the present value of quasi-rents for foreign firms. Entry by foreign firms occurs in any period until the present value of the quasi-rents are driven down to the one time start up costs of establishing a domestic presence for the foreign firm plus present value of the fixed costs of operating the domestic subsidiary. After about 10 years, the number of foreign varieties stabilizes for the duration of the model horizon at about 30% more than in the steady state. (See figure 5.) The increase in

imports, however, results in a substitution effect that reduces the demand for and price of domestic varieties; this shuts down investment and firm creation for the domestic variety for a period of about 6 years.

Although the increase in foreign varieties has the impact of decreasing the demand for domestic varieties of the intermediate good  $X$ , the domestic industry eventually stabilizes after 8 years rather than progressively going into demise. (See figure 4.) The principal reason for this is that the marginal productivity of domestic  $X$  in  $Y$  production increases as use of domestic  $X$  in  $Y$  declines. The entire labor force is employed in the production of  $Y$ , and it is not possible to reduce labor usage applied to domestic  $X$  without also reducing labor usage in imported  $X$ . Thus, as domestic  $X$  declines due to substitution toward cheaper imported  $X$ , its marginal product increases to eventually arrest the further decline of the domestic  $X$  industry.

The transitional dynamics of the model in the early years are dominated by the increase in the number of foreign firms. The increase in the number of firms has an immediate impact on the productivity in the final good sector inducing output of the final good sector to increase in the first year. This immediate increase in productivity and output of the final goods sector allows the economy to satisfy two constraints painlessly: (1) the economy is able to invest more in intermediate goods (it takes capital to produce the foreign variety) without reducing consumption in the short run relative to the steady state. Although the economy faces a Ramsey problem of determining the optimal tradeoff between consumption and investment, the tradeoff is within the framework of an expanded choice set relative to the steady state. In fact, the economy consumes about 7 percent more in the initial years compared with the benchmark steady state (see figure 1); and (2) despite the period by period balance of trade constraint, the economy is able to import more foreign intermediate varieties, without reducing its imports of final goods. The economy meets its balance of trade constraint by exporting more of the final good. Thus, reducing the tariff does not result in any adjustment costs in this model except for the losses that accrue to the specific capital owners in the domestic intermediate goods sector. The surge in productivity results in both a "level" effect and a growth effect regarding the increase in consumption. The level effect can be observed by the jump in consumption in the first year. In

addition, however, due to an increase in the rental rate on capital (figure 3), the long run growth rate increases from 2 to 2.1 percent.<sup>12)</sup>

### 3.2 Tariff Reduction with Spillovers

In this scenario, we cut the tariff on both final and intermediate imports from 20% to 10%, starting in the initial period. Crucially, we allow an increase in the number of foreign firms to decrease the blueprint costs for domestic firms, with a spillover elasticity equal to four percent. The equivalent variation of this scenario is 10.9 percent of the present value of consumption, which differs by only a small amount from the 10.7 percent for EV in the central model without spillovers.

The decrease in the tariff has the effect of increasing the number of foreign varieties, just as it does in the central model. With spillovers, however, an increase in the number of foreign varieties has two competing effects on investment in the domestic variety of  $X$ . On the one hand, as the number of foreign varieties increases, the demand for the domestic variety decreases, so the quasi-rents available for domestic firms decreases--decreasing the likelihood of domestic investment. On the other hand, the costs of domestic blueprints decreases with the number of varieties--increasing the likelihood of investment. In our formulation of spillover effects, a 100 percent increase in the number of foreign varieties relative to the steady state, reduces the blueprint costs of domestic firms by roughly 4 percent relative to the steady state blueprint costs. With these parameters, the spillover effect dominates after about 6 years, after which investment in domestic firms resumes. Relative to their steady state value, the number of domestic firms bottoms out at about 90 percent of their steady state value after about 7 years, and climbs to the benchmark steady state value by

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<sup>12)</sup> In this model the domestic and international rental rates on capital are decoupled, so a tariff reform produces a permanent increase in the domestic interest rate and a larger long-run increase in the growth rate. The *domestic* interest rate is computed using the price of final consumption. This rate can temporarily depart from the international rental rate on capital in the model with perfect capital markets due to Armington differentiation of domestic and imported goods. In the long run, the domestic interest rate and the international rate converge asymptotically.

It may appear puzzling that with spillovers, where the domestic industry has its costs reduced by foreign varieties, the economy does not gain a significantly larger amount. The reason is that what is most important to the welfare increase is the number of varieties rather than the geographic source of them. With spillovers, once the profitability of investment is restored for the domestic industry producing good  $X$ , growth of new foreign varieties falls—so there are more domestic firms and varieties, but fewer foreign varieties. The loss of productivity due to the loss of foreign varieties almost fully offsets the gain in welfare due to the increased number of domestic varieties.

### **3.3 Constant Returns to Scale (No Variety Multiplier)**

In this model, we replace increasing returns to scale and imperfect competition in the intermediate sector with constant returns to scale and perfect competition. Then only total output of the intermediate is important (numbers of varieties are not counted), so there is no variety productivity effect. Although consumers and decisions by investors optimize the consumption-capital stock choice as in a Ramsey model, there is no endogenous growth.

Equivalent variation for this scenario drops to 0.5 percent of the present value of consumption over the infinite horizon. Without the variety multiplier, there is neither the initial “level” effect in consumption nor the growth rate effect that obtained in our central and spillover models. Transitional dynamics are then more painful, since in order to finance the additional investment in the earlier period, consumption falls in the early years relative to the steady state. This result is similar to the results of Rutherford and Tarr (1997) who showed that a Ramsey multisector model with constant returns to scale is insufficient to generate the large welfare gains claimed for the trade liberalization paradigm.

### **3.4 Impact of Alternate Replacement Taxes**

Except for the scenarios discussed in this subsection, we have employed a consumption tax as our replacement tax. In the scenarios described here, we use two alternate taxes as the replacement tax for the lost tariff revenue: a tax on output; and a tax on capital. The impact on the path of consumption, as a function of the three replacement taxes, are presented in figure 10.

The curve labeled Consumption Tax is the same curve as in figure 1. Consumption increases to between 7 and 12 percent of benchmark consumption during the model horizon. The consumption tax is a Lump Sum distortionless tax in our model, but a tax on domestic output introduces certain inefficiencies. In particular, a domestic output tax discriminates against domestic output in favor of imports, and against final output in favor of intermediate production. As a result of the relative inefficiency of the domestic output tax, the path of consumption is cut by about 40-50 percent relative to the one with a tax on consumption and the equivalent variation is reduced to a gain of 6.7 percent of the present value of consumption..

Finally, the tax on capital produces a consumption path that is inferior to the one with an output tax, but preferable to the benchmark path with the tariff in place, i.e., the tax on capital is the most inefficient of our three replacement taxes, but is better than a tariff in our model. In our model, the intermediate good X uses capital intensively since only intermediate production uses capital as a primary input and only final goods use labor as a primary input.<sup>13)</sup> A tax on capital then discourages the introduction of new varieties since it discourages the investment required for the introduction of new varieties of products and discourages the production of intermediates relative to the production of final goods. The economy loses the productivity boost from the varieties and the gain in equivalent variation is less than only 4.7 percent of the value of consumption. These results illustrate the importance of efficient tax replacement. With inappropriate replacement tax mechanisms, the gains from trade liberalization can be drastically cut.

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<sup>13)</sup>Each good is used as an intermediate input in production of the other good, and thus both goods use both primary factors of production indirectly.



### 3.5 Capital Flows

In this scenario, the tariff is reduced from 20% to 10%, but the country is assumed to be able to borrow on international capital markets provided that the borrowing is repaid within the model horizon. Then the period-by-period balance of payments constraint is replaced by the constraint that the present value of its exports less imports is zero over the model horizon, and all other assumptions in the central model remained unchanged. In this scenario Hicksian equivalent variation (EV) is 37 percent of the present value of benchmark consumption over the infinite horizon. There is an initial jump in consumption of about 23 percent, and relative to the steady state, the wage rate increases by about 110 percent by the year 2050.

Why is the increase in EV with capital flows more than three times the EV value without capital flows? The decrease in the tariff implies that there is an incentive for new foreign firms to enter, as in the no capital flows model. The ability of the country to borrow, however, allows the country to run trade deficits and import much more in the periods immediately following tariff reduction. These additional imports are used to finance the start up capital of new foreign firms and to pay for the additional imports of foreign varieties. Foreign firms increase by almost 100 percent of their steady state value with capital flows by the year 2003, as opposed to an increase of about 35 percent of their steady state value without capital flows. The larger increase in foreign firms leads to a considerably larger increase in labor productivity and the wage rate in the early years.

What is interesting is that there is a much larger increase in the number of domestic firms with capital flows—in fact, the number of domestic firms increases dramatically relative to the steady state value by the end of the model horizon. This is explained by a real exchange rate effect. The economy finds it optimal to run trade deficits in the early years of the model. These trade deficits finance additional import varieties and additional consumption in the early years.<sup>14)</sup> The capital inflows in the early years result in less real exchange

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<sup>14)</sup>The latter occurs because consumers optimize consumption over the model horizon subject to their lifetime income constraint or permanent income. With the ability to borrow on international capital markets, consumers can

rate depreciation in the early years of the model (in fact, they result in real exchange rate appreciation in the first two years); but the capital outflows in the later years of the model result in a strong real exchange rate depreciation in those years. (See figure 2.) The steeper real exchange rate depreciation with capital flows in the years following 2020 (compared with central assumptions) raises the costs of importing foreign varieties in those years, and shifts demand toward domestic varieties. Domestic agents, who fully anticipate future real exchange rate movements, recognize profit opportunities and begin to invest by the year 2003. Among the models we consider, it is perhaps ironic that the model with capital flows, where we see the largest initial increase of foreign firms, ultimately leads to by far the strongest resurgence of domestic firms, even compared to the model with spillovers.

### 3.5 Sensitivity Analysis

In table 4 we present the results of our sensitivity analysis for the key parameters in our model, and we investigate the impact of different tariff changes. We present the Hicksian equivalent variation for each scenario (with the approximation for the infinite horizon), and the growth rates calculated over three time horizons: 1997-2010; 1997-2050; and 2049-2050, which is the projected growth rate into the infinite horizon. Except for the last three rows, in all scenarios the tariff rate is reduced from 20 to 10 percent.

As a point of reference, in row 0 we present the results obtained with our central assumptions, previously presented in row 1 of table 3. The result from row 1 illustrates that the larger the share of imported in intermediate use ( $\theta$ ), the larger the EV gains. The reason is that for a given ten percent cut in the tariff, the same proportional effect on the share of imports, generates more imported varieties, with the consequent productivity boost, when this share is high. For the share of intermediates in final production ( $\alpha$ ), there are offsetting effects: a higher share of intermediates in final production should increase the number of varieties

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smooth consumption more easily.

because again the proportional change induced by a ten percent tariff cut should induce a larger increase in the number of varieties; but the larger is  $\alpha$ , the smaller is the variety multiplier for any number of varieties. Thus, the impact of a change in this parameter on EV is ambiguous, and our two simulations presented in rows 2 and 3 along with the central model show that EV as a function of  $\alpha$  is not monotonic in the range of our central elasticity values.

In the benchmark steady state, the rental rate on capital is 5 percent and the growth rate is 2 percent. It is shown in appendix A that as these two rates approach each other, a given permanent increase in consumption over the infinite horizon yields a larger EV. In rows 4 and 5, we illustrate the magnitude of the change by varying each of these rates by one percent from the benchmark.

The results in row 6 indicate that, as is typical in comparative static models, the more elastic are the substitution possibilities, the greater the gains. In particular, with a larger elasticity of transformation, the economy is able to export more in response to a real exchange rate depreciation following tariff reduction, which allows it to pay for more imports; and the additional intermediate imports provide a productivity boost through the additional varieties. The impact of this parameter is quite strong, as EV increases from 10.7 to 17.1 percent with a doubling of the elasticity of transformation.

Given that many developing countries in the past 30 years have started from protection levels well above 20 percent and have implemented trade liberalizations considerably in excess of a ten percent tariff cut, in rows 7, 8 and 9 we examine the impact of cutting the tariff from 20 percent to zero, from 40 percent to 30 percent and from 40 percent to zero. For the results in rows 8 and 9, we generated a new baseline steady state growth path with a 40 percent tariff in place. The results of rows 7 and 9 show that the gains are very substantial for larger tariff cuts—the increase in EV from cutting the tariff from 40 percent to zero is more than 50 percent, which is more than double the gain of a cut from 20 percent to 0. Based on measurement of Harberger triangles, comparative static models also produce the result that the gains increase more than proportionately with the size of the tariff cut; but the result here is based on the fact that in our simulations

the number of varieties more than doubles with a doubling of the tariff cut.

## **5. Application to the Uruguay Round Tariff Cuts of Five Developing Economies**

In order to assess whether the large welfare results obtained above are dependent on possibly unrealistic parameter values, we apply this model to five countries: Argentina, Brazil, Korea, Malaysia and Thailand. We simulate the impact of the tariff cuts only on the intermediate products that these countries agreed to as part of their Uruguay Round commitments. That is, we ignore the tariff cuts they made on final products, as well as any liberalization in services.

For these countries, we employ the "GTAP" dataset (see Gelhar et al., 1997) and aggregate the following GTAP sectors into our single intermediate goods sector: pulp and paper; chemicals, rubber and plastics, non-metallic mineral products, primary ferrous metals, non-ferrous metals, fabricated metal products, transport industries, machinery and equipment, other manufacturing products, and other services (private). The resulting parameter values, including the tariff cuts are presented in table 5. Although all countries have a share of intermediates over 60 percent, the share of imports in intermediates varies from 7 percent in Brazil to 71 percent in Malaysia. Tariff cuts on intermediates varies from 2 percent for Malaysia to 8 percent for Brazil.

We examine the impact of these Uruguay Round tariff cuts in two models: first in our endogenous growth model with central assumptions; and next in a constant returns to scale Ramsey model. In our central model, the Hicksian equivalent variation increase ranges from 1.4 to 7.8 percent of the present value of consumption over time. The largest value is in Thailand, which is the only country of the five with a large share of imported intermediates, and a relatively large tariff cut of seven percent. Argentina's low share of imported intermediates and only five percent tariff cut explains its relatively low welfare gain.

These results are not intended to be a precise estimate of the gains from the Uruguay Round for these economies (see Harrison, Rutherford and Tarr, 1997a). Rather they suggest that the our large welfare gains

are not based on implausible parameter values. In the Ramsey model, the lack of variety induced productivity increases results in quite small welfare increases, ranging from 0.1 percent in Korea and Malaysia to 0.4 percent in Thailand. Again, this indicates that estimated welfare gains are in the range of the estimates from competitive, static model.

## **5. Summary and Conclusions**

This paper has investigated the effects of tariff liberalization in a small open economy in which endogenous growth is linked to the introduction of new products by domestic or foreign firms. We have developed a dynamic numerical model which allows us to trace out the dynamic adjustment path of all variables and approximate the infinite-horizon welfare consequences of a change in policies. In our central scenario, the tariff is cut from 20 percent to 10 percent, and we consider the impact both when the country can access international capital markets and when it cannot.

We found that the welfare gain (Hicksian equivalent variation) from tariff reform is 10.7 percent of the present value of consumption in our central model,, a significant increase considering that the benchmark tariff rate is only cut from 20 percent to 10 percent. We investigated the sensitivity of our results to all of the key parameters in the model and found that the welfare estimates for the same tariff cuts ranged up to 37 percent with capital flows, and down to 4.7 percent with inefficient replacement taxes. Larger tariff cuts, which have characterized the experience of many developing countries in the past 30 years, resulted in increases in the estimates of the welfare gains that were at least proportionate to the size of the cut.

We applied the model to five developing countries and estimated the impact of the tariff changes which they plan to undertake as part of their Uruguay Round commitments. The gains of 0.7 percent to 7.8 percent that we estimate for these countries are large in relation to the comparative static or comparative steady state estimates of the effects of the Uruguay Round for these countries.

Clearly these results support the paradigm that trade liberalization leads to significant income

increases, but they also illustrate the crucial importance of complementary reforms to fully realize the potential gains from the trade reform. Notably, with the ability to access international capital markets, the gains are more than doubled. Moreover, use of inefficient replacement taxes will significantly reduce the gains. These combined results show that while there are indeed large gains possible from trade liberalization, complementary macroeconomic, regulatory, and financial market reforms to allow capital flows and efficient alternate tax collection are crucial to realize the large gains.

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**Table 1: Input Assumptions for Stylized Model**

Value Shares		Other Parameters	
Intermediate value share ( $\alpha$ )	66 %	Baseline Interest Rate	5 %
Import Value Shares		Baseline Growth Rate	2 %
Intermediate Demand ( $\theta_x$ )	50 %	Capital Depreciation Rate	7 %
Final Demand ( $\theta_c$ )	20 %	Baseline Tariff Rate	20 %
Domestic intermediate	0 %	Elasticities of Substitution	
Imported intermediate	75 %	Intertemporal	0.5
Domestic intermediate capital	50 %	Export Supply	1
Imported intermediate capital	75 %	Import Demand	1
Capital Value Shares			
Domestic intermediate	75 %		
Imported intermediate	25 %		
Blueprint Share of Fixed Cost			
Domestic intermediate	90 %		
Imported intermediate	10 %		

**Table 2: Benchmark Social Accounts (steady-state equilibrium)**

	Y	X <sub>D</sub>	X <sub>M</sub>	M	I	FD
PD	0.76	-0.11			-0.25	-0.40
PM			-0.16	0.29	-0.02	-0.10
PX	-0.66	0.33	0.33			
PI					0.28	-0.28
PFX	0.24			-0.24		
PL	-0.34					0.34
RK		-0.11	-0.05			0.16
MK		-0.11	-0.11			0.22
T				-0.05		0.05

*Key:*

Y	Production of final	PD	Final goods
X <sub>D</sub>	Domestic	PM	Final goods (imports)
X <sub>M</sub>	Imported intermediate	PX	Final goods (exports)
M	Imports	PI	Investment
I	Investment	PF	Foreign exchange
FD	Final Demand	PL	Wage rate
		RK	Return to capital
		M	Markup revenue
		T	Tariff revenue

**Table 3: Estimated Welfare and Growth Effects of Tariff Reduction\***

Model	EV $\infty$	G2010	G2050	Gterm
1. Central Assumptions	10.7	2.6	2.2	2.1
2. Spillovers	10.9	2.6	2.2	2.1
3. Constant Returns to Scale	0.5	2.0	2.0	2.0
4. Output Tax Replacement	6.7	2.5	2.1	2.0
5. Capital Income Tax Replacement	4.7	2.4	2.1	2.0
6. Capital Flows	37.0	4.2	2.7	2.2

\* Parameter choices for all models are shown in table 1. Unless otherwise indicated, all models include: lump sum replacement taxes, no spillover effect of new foreign varieties on the domestic cost of new blueprints, and period by period balance of trade constraint..

EV $\infty$	Hicksian equivalent variation over the infinite horizon as a percent the present value of benchmark steady state consumption
G2010	Average consumption growth 1997-2010
G2050	Average consumption growth 1997-2050
Gterm	Terminal growth rate (from 2049 to 2050)

**Table 4: Sensitivity Analysis**

Parameter*	Central Value	Sensitivity Value	Balance of trade constraint for each period:			
			EV $\infty$	G2010	G2050	Gterm
0			10.7	2.6	2.2	2.1
1. $\theta_i$	0.5	0.25	4.6	2.3	2.1	2.1
2. $\alpha$	0.66	0.80	11.0	2.5	2.3	2.2
3. $\alpha$	0.66	0.50	11.3	2.8	2.2	2.0
4. G	0.02	0.03	14.6	3.8	3.3	3.1
5. R	0.05	0.04	13.0	2.7	2.2	2.1
6. $\eta_{DX}$	1	2	17.1	3.1	2.3	2.1
7. Tariff change	20% to 0%		23.7	3.4	2.5	2.2
8. Tariff change	40% to 30%		9.1	2.6	2.2	2.1
9. Tariff change	40% to 0%		51.6	4.4	3.1	2.1

\* The counterfactual scenarios use the sensitivity value. The central value is listed for reference only.

Key:

EV $\infty$	Hicksian equivalent variation over the infinite horizon
G2010	Average consumption growth 1997-2010
G2050	Average consumption growth 1997-2050
Gterm	Terminal growth rate (from 2049 to 2050)
$\theta_i$	Import share of intermediate inputs
$\alpha$	Intermediate share of aggregate cost
G	Baseline growth rate
R	Baseline interest rate
$\eta_{DX}$	Elasticity of transformation in aggregate production (domestic versus exports)
Tariff	Alternative pre-existing tariff rates and tariff reform programs (in the reference case, 20% is cut to 10%)

**Table 5: Evaluation of the Uruguay Round Tariff Cuts for Five Developing Countries,  
with and without Product Variety Productivity Impacts**

Country and Model	Data				Welfare and Growth Estimates			
	intermediate value share	import share of intermediates	benchmark tariff	post- Uruguay Round tariff	EV $\infty$	G2010	G2050	Gterm
<b>I Product Variety Productivity and Capital Flows</b>								
A. Korea	0.6	0.2	15.0	8.0	2.6	2.2	2.1	2.0
B. Malaysia	0.7	0.7	8.0	6.0	4.0	2.3	2.1	2.0
C. Thailand	0.6	0.6	32.0	25.0	7.8	2.5	2.2	2.0
D. Argentina	0.9	0.1	28.0	23.0	0.7	2.0	2.0	2.0
E. Brazil	0.6	0.1	30.0	22.0	1.4	2.1	2.0	2.0
<b>II Constant Returns to Scale and Capital Flows</b>								
A. Korea					0.1	2.0	2.0	2.0
B. Malaysia					0.1	2.0	2.0	2.0
C. Thailand		- same as above -			0.4	2.0	2.0	2.0
D. Argentina					0.2	2.0	2.0	2.0
E. Brazil					0.1	2.0	2.0	2.0

**Key** : See table 3.

**Source** : GTAP dataset for data, see Gehlhar *et al.* (1997); and authors' estimates.

## Appendix A: Growth and Welfare over the Infinite Horizon

This appendix derives algebraic relations relating changes in the growth rate of consumption to the equivalent variation in infinite-horizon consumption. It then shows how these formula may be employed to provide consistent estimates of infinite horizon welfare based on equilibrium choices over a finite horizon. These functions relating growth to welfare are interesting for two reasons. First, they provide some intuition as to the importance of changes in growth rates vis-a-vis the more conventional static efficiency estimates of the welfare cost of protection. Second, these equations are required for estimating the infinite-horizon welfare change, given welfare changes over the time horizon of the model, the terminal consumption level and the terminal (steady-state) consumption growth rate.

We begin with a constant-elasticity of substitution utility function:

$$U(C) = \left[ \sum_{t=0}^{\infty} \Delta^t C_t^{\rho} \right]^{1/\rho}$$

The elasticity of intertemporal substitution is given by  $\sigma = 1/(1 - \rho)$ . The model is based on ordinal utility, so the optimal consumer choices are unaffected by monotonic transformations of the utility function. For example, this utility function is equivalent to:

$$U(C) = \sum_{t=0}^{\infty} \Delta^t \frac{C_t^{1-1/\sigma}}{1-1/\sigma}$$

*The advantage of the former function is that because it is linearly homogeneous in consumption levels ( $U(\lambda C) = \lambda U(C)$ ), a one percent change in  $U$  corresponds to a one percent equivalent variation in income. If we let  $\bar{C}$  denote a reference consumption path, and let  $C$  denote an alternative time path of consumption levels, the equivalent variation in infinite-horizon welfare then corresponds to:*

$$EV_{\infty} = \frac{\left[ \sum_{t=0}^{\infty} \Delta^t C_t^p \right]^{1/p}}{\left[ \sum_{t=0}^{\infty} \Delta^t \bar{C}_t^p \right]^{1/p}} - 1$$

We now evaluate the equivalent variation of a permanent change in the consumption growth rate, assuming that the initial level of consumption in period  $t=0$  is held constant. Take  $\bar{C}_t = (1 + \bar{g})^t$  and  $c_t = (1 + g)^t$ . It then follows that the equivalent variation in income is:

$$EV = \left[ \frac{1 - \Delta (1 + \bar{g})^p}{1 - \Delta (1 + g)^p} \right]^{1/p} - 1$$

In order to relate this expression to the calibrated equilibrium calculations such as those conducted in our paper, it is helpful to replace the utility discount parameter,  $\Delta$ , by an expression based on the baseline growth rate and interest rate. In other words, in order to compute a baseline equilibrium, we do not begin with a given value of the utility discount factor. We instead assume a balanced baseline growth path with a given growth rate ( $\bar{g}$ ), and a given interest rate ( $\bar{r}$ ). It is then a simple matter to show that the utility discount factor is given by:

$$\Delta = \frac{(1 + \bar{g})^{1/\sigma}}{1 + \bar{r}}$$

Substituting into the equivalent variation equation, we then have:

$$EV = \left[ \frac{\bar{r} - \bar{g}}{1 + \bar{r} - (1 + \bar{g}) \left( \frac{1 + g}{1 + \bar{g}} \right)^p} \right]^{1/p} - 1$$

This expression provides us with a useful check on the magnitude of welfare gains arising from our calculations. Figure A1 simply computes the Hicksian welfare metric for growth rate increases ranging from



0 to 1%. Two lines correspond to baseline growth rates of 1% and 2%. Both functions are based on a baseline interest rate of 5% and an intertemporal elasticity of substitution equal to one half. We see that growth rate changes of a 0.5% produce welfare changes on the order of 10 to 15%, depending on the initial growth rate. Holding constant the baseline interest rate, the welfare change increases in the baseline growth rate.

Figure A2 investigates the sensitivity of this function to the baseline interest rate. As expected, the higher the interest rate, the lower the welfare gain associated with a permanent change in the growth rate. A higher interest rate implies a larger discount on future consumption increases, so that future gains in consumption are less important.

Figure A3 illustrates the relationship between the intertemporal elasticity of substitution and the welfare gain associated with a half a percentage increase in the consumption growth rate. Again, the results are intuitive. The higher the elasticity of intertemporal substitution, the larger the achievable gain from an increase in future consumption. When the intertemporal elasticity is close to zero, an increase in the growth rate has no effect on welfare because period 0 consumption does not change. However, as the intertemporal elasticity increases from zero, the consumer benefits more as she is able to more easily substitute current consumption for future consumption.

In our model calculations, we adopt a finite-horizon model which approximates the infinite-horizon equilibrium. We apply terminal conditions which assure that terminal period investment is positive and increasing with aggregate GDP (See Lau, Palke and Rutherford 1997 for details on the terminal approximation.) Having computed equilibrium values for period 0 to  $T$ , we have an explicit utility index over consumption in these periods, but this index fails to account for consumption increase in the post-terminal period. We can approximate the infinite horizon welfare index, however, based on the following functions of the finite-horizon model: (i) the welfare index for periods 0 to  $T$ ,  $u_T$ , (ii) terminal period consumption,

$C_T$  and (iii) post-terminal growth,  $g_\infty$ . We produce an infinite-horizon welfare index based on the assumption that the economy exhibits steady-state growth at rate  $g_\infty$  from period  $T+1$  to the infinite horizon.

In order to lay out the formulae for this approximation, we begin by splitting the infinite-horizon welfare into two periods,  $t = 0$  to  $T$  and  $t > T$ . We assume a growth rate of  $\Delta_\infty = \frac{C_T - C_{T-1}}{C_T}$  for the post-terminal period, then:<sup>15)</sup>

$$\begin{aligned} U(C) &= \left[ \sum_{t=0}^{\infty} \Delta^t C_t^\rho \right]^{1/\rho} \\ &= \left[ \sum_{t=0}^T \Delta^t C_t^\rho + \sum_{t=T}^{\infty} \Delta^t \left\{ C_T (1+g_\infty)^{(t-T)} \right\}^\rho \right]^{1/\rho} \\ &= \left[ \sum_{t=0}^T \Delta^t C_t^\rho + C_T^\rho \frac{\Delta^T}{1 - \Delta(1+g_\infty)^\rho} \right]^{1/\rho} \end{aligned}$$

When working with a calibrated model, it may be easier to begin from a reference balanced growth path. Substituting for  $\Delta$  as above, and denoting the average consumption growth rate through period  $t$  as  $\bar{\Delta}_t$ , the equivalent variation in income can be written:

$$\begin{aligned} EV &= \left( \frac{\bar{r} - \bar{g}}{1 + \bar{r}} \right)^{1/\rho} \left\{ \sum_{t=0}^T \left[ \frac{1 + \bar{g}}{1 + \bar{r}} \left( \frac{1 + g_t}{1 + \bar{g}} \right)^\rho \right]^t \right. \\ &\quad \left. + \left[ \frac{1 + \bar{g}}{1 + \bar{r}} \left( \frac{1 + g_T}{1 + \bar{g}} \right)^\rho \right]^T \left[ 1 - \frac{1 + \bar{g}}{1 + \bar{r}} \left( \frac{1 + g_\infty}{1 + \bar{g}} \right)^\rho \right]^{-1} \right\}^{1/\rho} - 1 \end{aligned}$$

Alternatively, this expression can be written in terms of the welfare level through period  $T$  and the level and

---

<sup>15)</sup> In the finite horizon model we use a utility function,

$$U_T = \left( \sum_{t=1}^T \Delta^t C_t^\rho \right)^{1/\rho}$$

in which there is no additional "weight" on period  $T$  consumption. In the finite horizon model, a constraint on the terminal capital stock such that investment follows a steady-state growth path. Having computed the finite horizon equilibrium, we then compute the infinite horizon welfare index.

*growth rate of consumption in the post-terminal period, i.e.*

$$EV = \left\{ \theta_T U_T^\rho + (1-\theta_T) \left[ \frac{\gamma(g_\infty, \bar{g}) C_T}{\bar{C}_T} \right]^\rho \right\}^{1/\rho} - 1$$

*In which we define:  $\theta_T = \frac{1-\theta^T}{1-\theta}$ , where  $\theta = \frac{1+\bar{g}}{1+r}$  and:*

$$\gamma(g_\infty, \bar{g}) = \left[ \frac{1-\theta}{\left( \frac{1+\bar{g}}{1+g_\infty} \right)^\rho - \theta} \right]^{1/\rho}$$

*In a constant growth rate model, the term  $\gamma(g_\infty, \bar{g})$  is always unity, so the welfare then depends solely on the utility index through model horizon and the terminal consumption level relative to the original steady-state growth rate.*

## Appendix B: Benchmark Assumptions and Calibration

Consider the input data as outlined in Table 1. Scaling base year final goods output to unity, we then define imported and domestic intermediate inputs as:

$$x_M = \theta_i \alpha \quad \text{and} \quad x_D = (1 - \theta_i) \alpha.$$

Labor inputs for final goods production may then be inferred through exhaustion of product:

$$L_M = \theta_i (1 - \alpha) \quad \text{and} \quad L_D = (1 - \theta_i) (1 - \alpha).$$

Base year wage income is the sum of these values,  $L = L_D + L_M$ .

The intermediate value share determines markups over marginal cost, and this in turn defines markup revenues given assumed sales by firm type:

$$mk_f = x_f (1 - \alpha), \quad f \in \{D, M\}$$

Capital returns in intermediate goods production are defined as a fraction of variable cost:

$$vk_f = kvs_f (x_f - mk_f)$$

Imported inputs to intermediate goods production are also defined as a fraction of variable cost:

$$mx_f = mvs_f (x_f - mk_f)$$

Domestic inputs to intermediate production are determined by exhaustion of product:

$$dx_f = (1 - kvs_f - mvs_f) (x_f - mk_f)$$

The user cost of capital equals interest plus depreciation, so the initial capital stock in can then be inferred from capital returns:

$$kx_f = \frac{vk_f}{r+\delta}$$

Fixed costs of intermediate goods production equal the sum of recurring fixed costs and blueprints. We use a parameter  $fcshr_f$  to define how these shares are separated:

$$fc0_f = fcshr_f mk_f$$

Blueprints do not depreciate, so the value of a firm's equity is related to the base year dividends through the interest rate:

$$f_f = \frac{(1-fcshr_f) mk_f}{r}$$

Base year firm creation is determined by the steady-state growth rate (there is no depreciation of blue-prints in this model):

$$i_f = g f_f$$

Domestic and intermediate inputs to investment are based on the import value share in investment:

$$im_f = mvsif i_f \quad id_f = (1-mvsif) i_f$$

Base year capital investment in firms is sufficient to cover growth plus depreciation of the capital stock:

$$ix_f = kx_f (g + \delta)$$

Net investment by households in the intermediate goods sector equals the total value of blueprint and capital formation, less the value of markup revenue net of recurring fixed costs:

$$I = \sum_f i_f + ix_f - (mk_f + mk_f - fc_f)$$

As we assume that tariff revenues are returned to the consumer in a lump sum, we must determine base year tariff revenue and imports to final demand simultaneously. The following system of equations then determine base year tariff revenue ( $T$ ) and imports ( $c_m$ ):

$$T = \frac{t}{1+t} \left( c_m + \sum_f mx_f + im_f \right)$$

and

$$c_m = \theta_c (L - I + T)$$

Solving, we have

$$T = \frac{t \left( \theta_c (L - I) + \sum_f mx_f + im_f \right)}{1+t (1-\theta_c)}$$

Domestic consumption is then

$$c_d = (1 - \theta_c) (L - I + T)$$

Total demand for domestic output is equal to the sum of final demand, inputs to intermediate production, recurring fixed costs for intermediate demand, inputs to new firms and investment in capital goods for new firms:

$$D = c_d + \sum_f dx_f + fc_f + id_f + ix_f$$

We assume that both firm types supply to the domestic and import markets in the same proportions, we therefore use market share to define production to the domestic and export market by firm type.

$$d_D = (1 - \theta_x) D, \quad d_M = \theta_x D$$

Imports include those for final consumption, X production and X-sector investment:

$$M = \frac{c_m + \sum_f mx_f + im_f}{1+t}$$

The value of total exports equals the net of tariff value of imports. Imposing trade balance, the value of exports equals the value of imports deflated by the base year tariff: And then from our assumption of symmetry of export shares across domestic and foreign firms, we have:

$$e_M = \theta_x M, \quad e_D = (1 - \theta_x) M.$$

Figure 1: Consumption Path following Tariff Reform

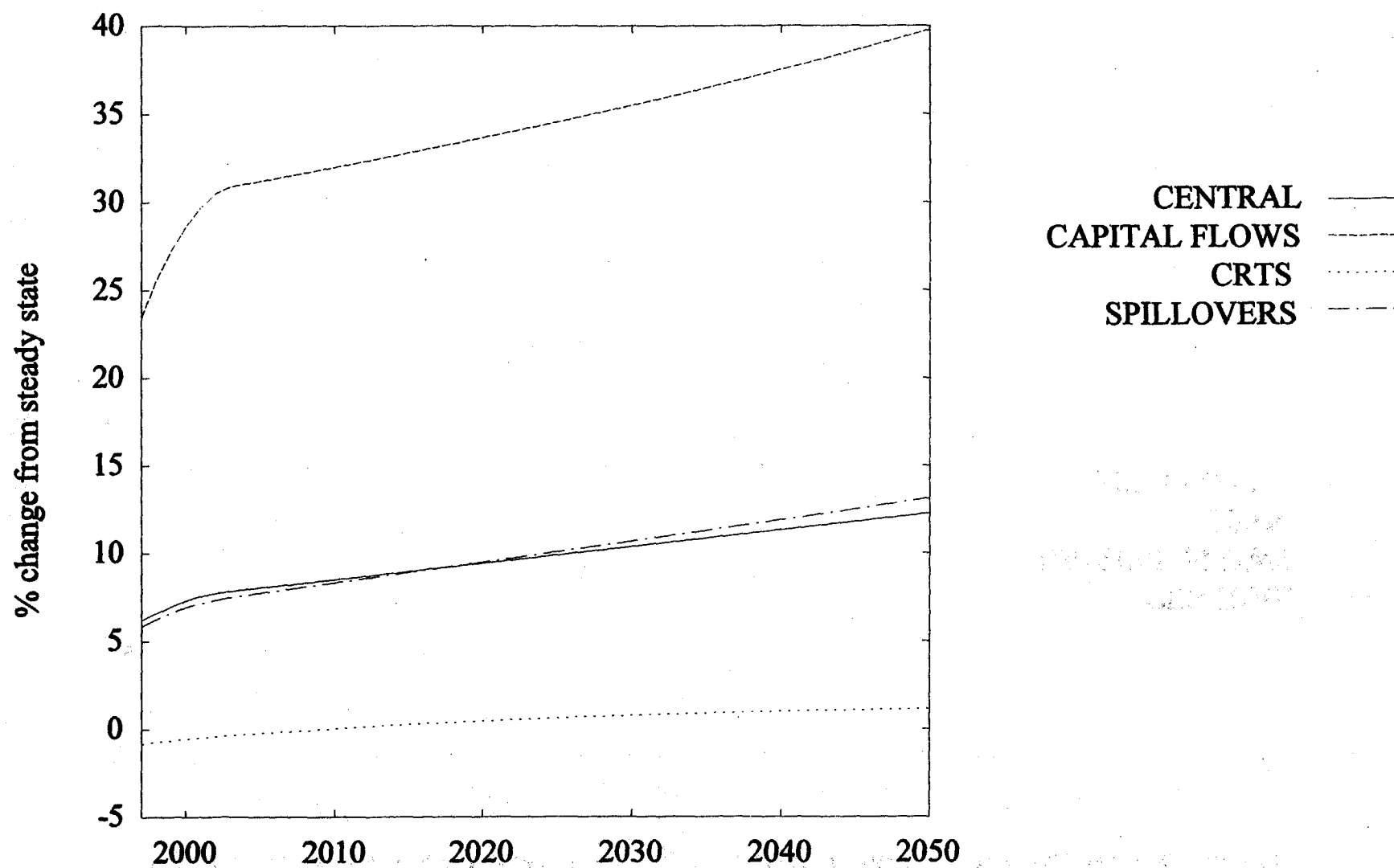


Figure 2: The Real Exchange Rate following Tariff Reform

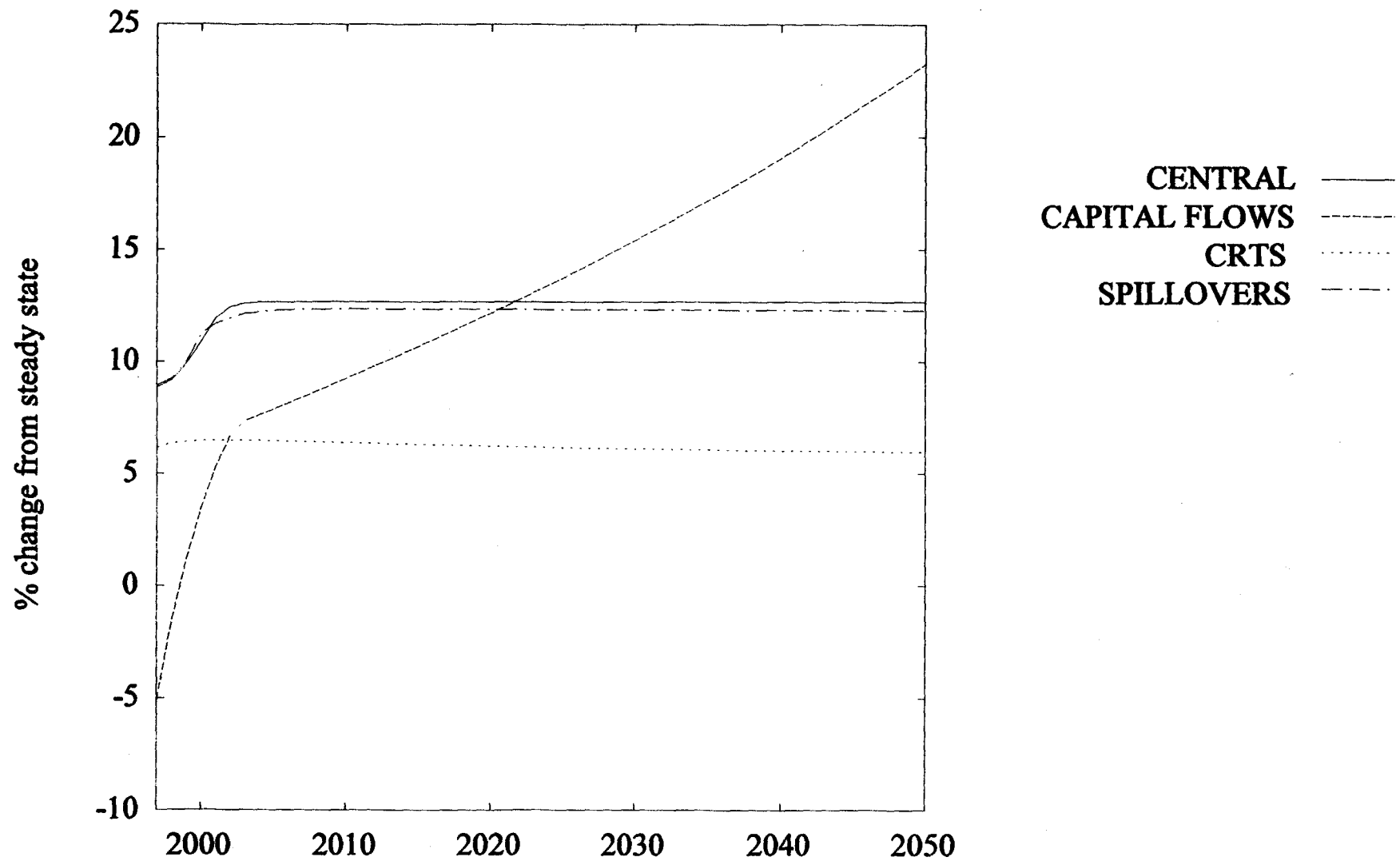




Figure 3: Interest Rate following Tariff Reform

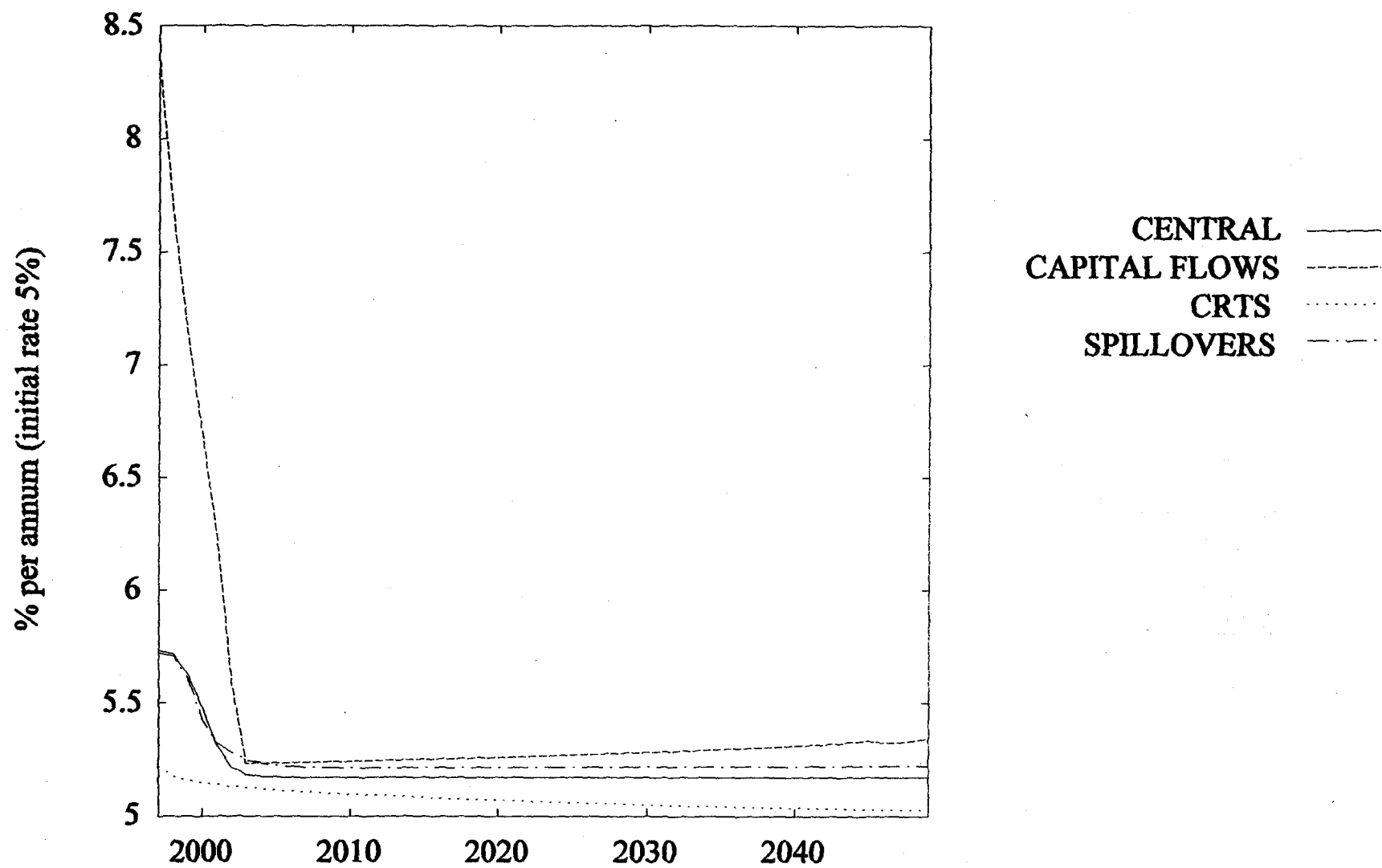


Figure 4: Domestic Firms following Tariff Reform

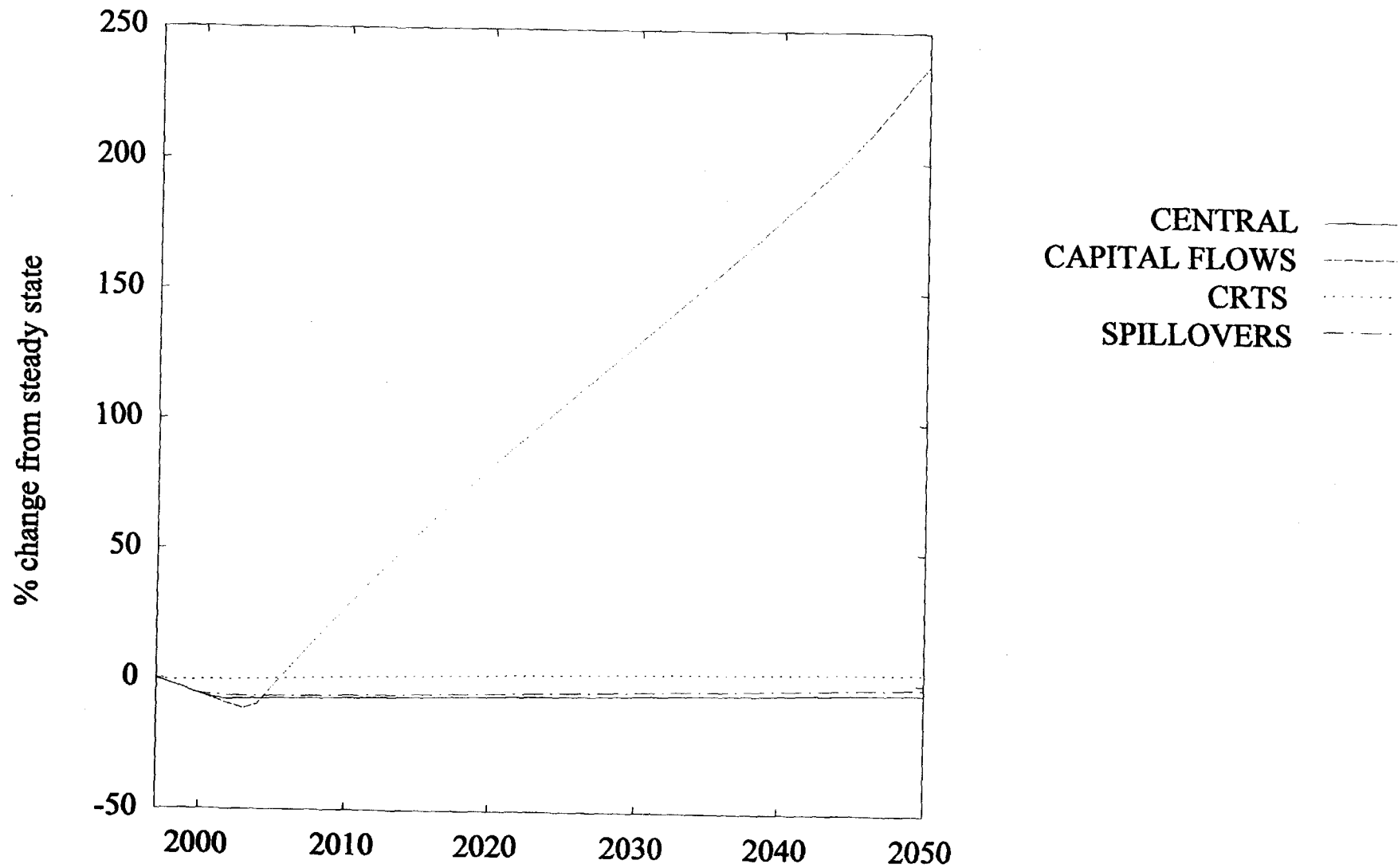


Figure 5: Foreign Firms following Tariff Reform

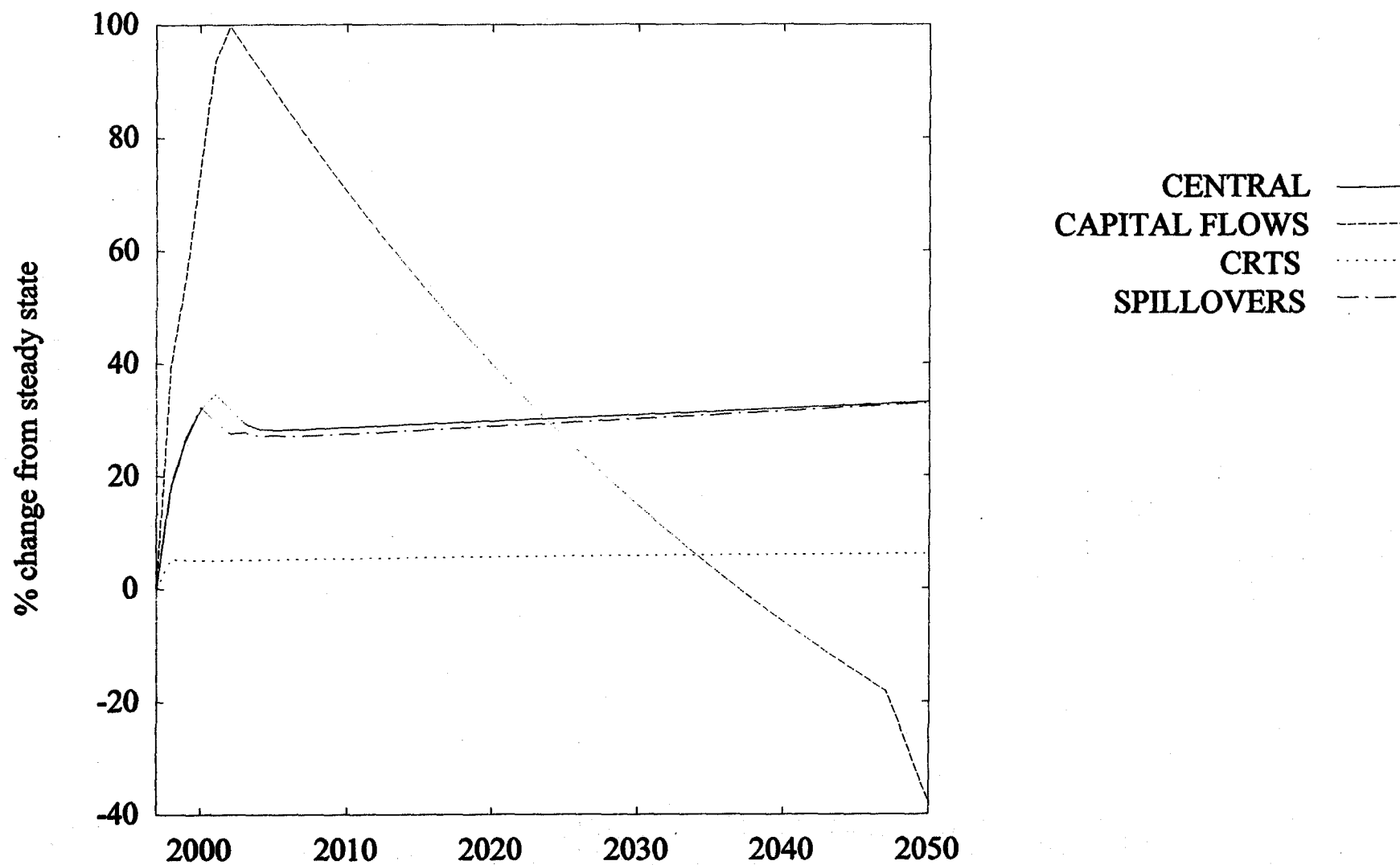
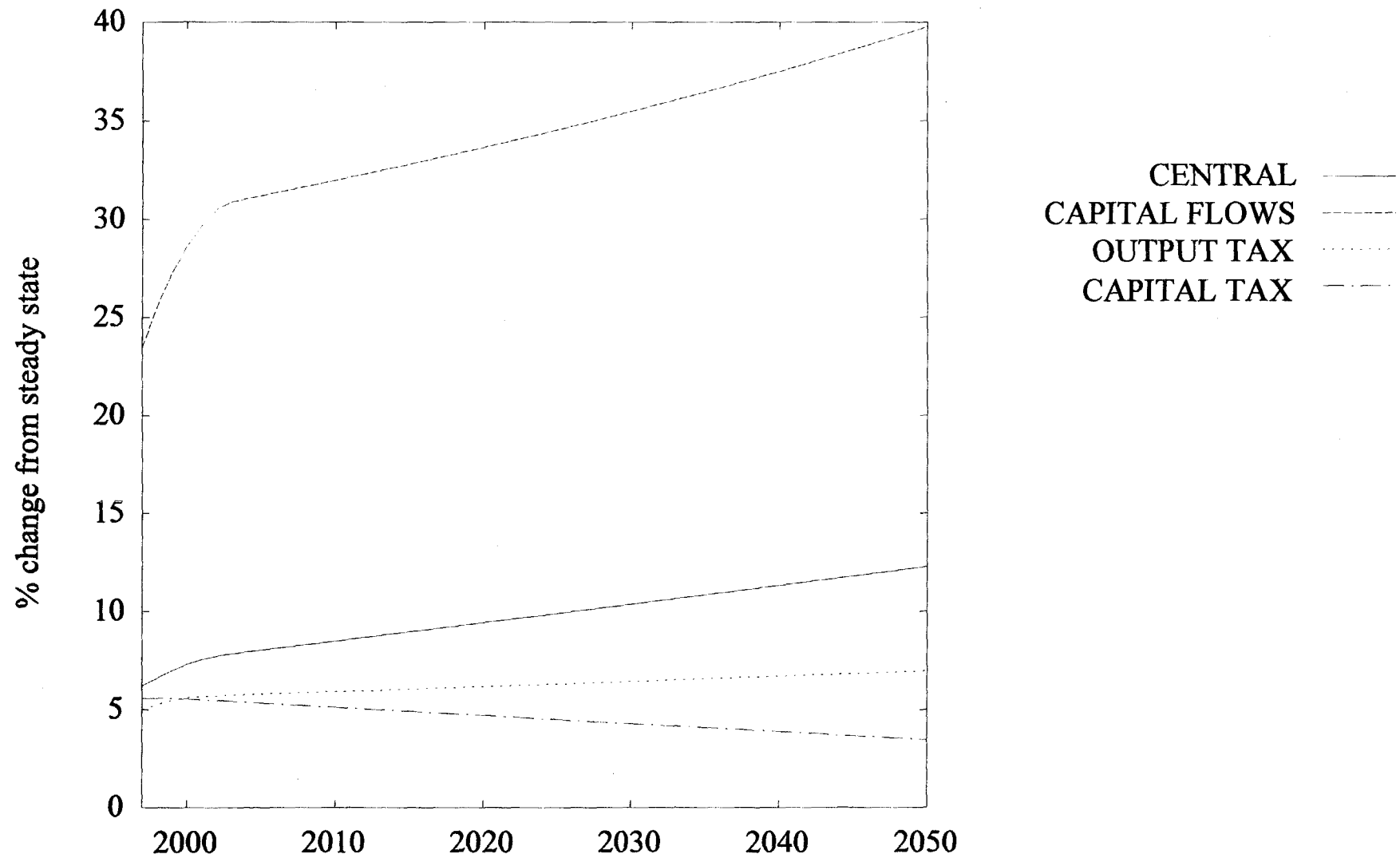


Figure 6: Consumption Paths for  
Alternative Replacement Taxes



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